

## WHAT IS CLAIMED IS:

1. A high strength alloy comprising:

a plurality of deposited microcrystalline films wherein said microcrystalline films alternate between a primary microcrystalline film comprised of a Group VIB transition metal and a secondary microcrystalline film comprised of a metal, a metal compound, a semi-metal, or a semi-metal compound;

wherein said secondary microcrystalline film has a crystal habit different from the body-centered-cubic habit of the metal of the primary microcrystalline film and has limited solubility or reactivity with respect to said metal at the consolidation and use temperatures of the alloy, and said secondary microcrystalline films are disposed between said primary microcrystalline films; and

wherein each of said primary microcrystalline films has a thickness of up to 1350 nanometers and wherein each of said secondary microcrystalline films has a thickness sufficient to arrest the growth of the crystallites of the primary films and prevent epitaxial growth between adjoining primary microcrystalline films.

2. The alloy of claim 1 wherein said secondary microcrystalline films each have a thickness that is less than the thickness of the primary microcrystalline films.
3. The alloy of claim 1 wherein said secondary microcrystalline films each have a thickness that is greater than the thickness of the primary microcrystalline films but less than 400 nm.
4. The alloy of claim 1 wherein said secondary microcrystalline film comprises a compound of tungsten.
5. The alloy of claim 4 wherein said compound of tungsten comprises tungsten carbide.
6. The alloy of claim 4 wherein said compound of tungsten comprises tungsten boride

7. The alloy of claim 1 wherein said secondary microcrystalline film comprises silicon carbide.

8. The alloy of claim 1 wherein said alloy further comprises a coating or a body having a surface finish (Ra) approximately the size of the grains in the body but not greater than 200 nm.

9. The alloy of claim 8 wherein said coating or body further comprises an exterior surface finished by electro-polishing, electro-chemical grinding, or chemical-mechanical finishing.

10. A high strength tungsten alloy comprising:

a plurality of adherent microcrystalline, chemically-vapor-deposited, films wherein said microcrystalline films alternate between a plurality of uniformly disposed tungsten films and a plurality of uniformly disposed secondary films comprised of a hard metal compound of tungsten; and

wherein the thickness of each of the tungsten films does not exceed 1350 nanometers; and

wherein said secondary films have a thickness sufficient to arrest the growth of the primary film crystallites and to prevent epitaxial growth between said tungsten films.

11. The alloy of claim 10 wherein said secondary films each have a thickness that is less than the thickness of the tungsten films.

12. The alloy of claim 10 wherein said secondary films each have a thickness that is greater than the thickness of the tungsten films but less than 400 nm.

13. The alloy of claim 10 wherein the thickness of any tungsten film does not differ in thickness from any of the other tungsten films in the adherent array by more than 2:1 and wherein the thickness of any secondary film does not differ in thickness from any of the other secondary films in the adherent array by more than 2:1.

14. The alloy of claim 10 wherein said tungsten films each have a thickness between 10 and 1000 nanometers.
15. The alloy of claim 10 wherein the thickness of the primary films do not exceed 100 nanometers each.
16. The alloy of claim 10 wherein the thickness of the secondary films is not greater than 20 nm.
17. The alloy of claim 10 wherein the thickness of the secondary films is not less than 1 nm.
18. The alloy of claim 10 wherein the flexural strength of the alloy exceeds 1800 MPa.
19. The alloy of claim 10 wherein the flexural strength of the alloy exceeds 5100 MPa.
20. The alloy of claim 10 wherein the alloy has a hardness (HV) of about 7.8 GPa and a Modulus of Resilience, determined using flexural strength in 3-point bending, of over  $10 \times 10^6$  Joules/m<sup>3</sup>.
21. The alloy of claim 10 wherein the alloy has a hardness (HV) of about 7.8 GPa and a Fracture Energy, determined using flexural strength in 3-point bending, over  $20 \times 10^6$  Joules/m<sup>3</sup>.
22. The alloy of claim 10 wherein the alloy has a hardness (HV) of over 15 GPa and a Modulus of Resilience, determined using flexural strength in 3-point bending, over  $15 \times 10^6$  Joules/m<sup>3</sup>.
23. The alloy of claim 10 wherein the alloy has a hardness (HV) of over 15 GPa and a Fracture Energy, determined using flexural strength in 3-point bending, over  $15 \times 10^6$  Joules/m<sup>3</sup>.

24. The alloy of claim 10 wherein the alloy has a hardness (HV) of over 10 GPa and displays nonlinear stress-strain behavior, and such nonlinear behavior increases at elevated temperatures.

25. The alloy of claim 10 wherein said alloy has been heat annealed at a temperature of 1500 °C for one hour in an inert environment causing a reduction of hardness to less than 6 GPa but a maintenance of strength of at least 1350 MPa.

26. The alloy of claim 10 wherein said alloy further comprises a coating or a body having a surface finish (Ra) better than 250 nm.

27. The alloy of claim 10 wherein said coating or body further comprises an exterior surface finished by electro-polishing, electro-chemical grinding, or chemical-mechanical finishing.

28. A method of making a high strength alloy, the method comprising the steps of:

depositing said Group VIB transition metal in a primary film by physical vapor deposition or chemical vapor deposition on a substrate;

using the same deposition method to deposit an adherent film of a metal or a semi-metal compound having a crystal habit different from the body-centered-cubic habit of the metal of the primary film and having limited solubility or reactivity with respect to said body-centered-cubic metal at the deposition and use temperatures of the alloy;

wherein the deposited film of said metal or semi-metal compound is of a thickness sufficient to arrest the growth of the crystallites of the primary film and prevent epitaxial growth between adjoining primary microcrystalline films; and

repeating the alternate deposition of the adherent Group VIB transition metal films and the adherent metal or semi-metal compound films until a plurality of such alternate films is made to the required thickness of the coating or body.

29. The method of claim 28 wherein the primary film is deposited so that it has a thickness not greater than 1350 nm in thickness.

30. The method of claim 28 wherein the deposition method comprises chemical vapor deposition.

31. The method of claim 28 wherein the Group VIB transition metal comprises tungsten.

32. The method of claim 28 wherein the metal or semi-metal compound comprises tungsten carbide.

33. The method of claim 28 wherein the metal or semi-metal compound comprises tungsten boride.

34. The method of claim 28 wherein the metal or semi-metal compound comprises silicon carbide.

35. A method of making a high strength alloy of a Group VIB transition metal, the method comprising the steps of:

supplying a flow of a precursor gas containing said Group VIB transition metal to a gas-tight, anaerobic, chemical-vapor-deposition, reactor vessel containing a heated mandrel or substrate;

decomposing said precursor gas on the heated mandrel or substrate to make a deposited primary film of said Group VIB transition metal, the thickness of which is not greater than 1350 nm;

continuing the flow of said precursor gas and adding an additional decomposable gas containing either a non-metal or semi-metal capable of combining with said Group VIB transition metal to make a hard metal compound of said metal;

passing the mixture of said precursor gas and said additional gas over the heated mandrel or substrate and decomposing them to form a secondary film of said hard metal compound of said Group VIB transition metal, which secondary film is adherent to the previously-deposited primary film, and which secondary film is of sufficient thickness to arrest the growth of the crystallites of the primary films and to interrupt the epitaxial growth of the metal crystallites of the primary film;

stopping the flow of the additional gas, but continuing the flow of the gas containing said Group VIB transition metal and decomposing said gas on the heated mandrel or substrate to make another deposited primary film of said metal, the thickness of which does not exceed 1350 nanometers, which primary film is adherent to the previously-deposited secondary film;

again adding the additional gas to repeat the formation of another secondary film of a hard metal compound, adherent to the previously-deposited primary film; and

continuing the alternate deposition of primary and secondary films until the desired thickness of the alloy is achieved.

36. The method of claim 35 further wherein the secondary films formed each have a thickness that is less than the thickness of the primary films.

37. The method of claim 35 wherein said the secondary films formed each have a thickness that is greater than the thickness of the tungsten films but less than 400 nm.

38. The method of claim 35 wherein the primary film deposited is tungsten.

39. The method of claim 38 wherein the secondary film deposited is tungsten carbide.

40. The method of claim 38 wherein the secondary film deposited is tungsten boride.

41. The method of claim 38 wherein the precursor gas for the deposition of the primary films comprises a volatile tungsten chloride.

42. The method of claim 38 wherein the deposition process is conducted at a total pressure greater than 700 Pa and less than 33,000Pa.

43. The method of claim 38 wherein the thickness of the deposited primary films of tungsten is between 10 and 1000 nanometers.

44. The method of claim 38 wherein the thickness of the deposited primary films of tungsten do not exceed 100 nm.

45. The method of claim 35 wherein the thickness of the secondary film is at least 1 nm.

46. The method of claim 35 wherein the alloy comprises a coating or a body having a surface finish (Ra) better than 250 nm.

47. The method of claim 35 wherein the alloy comprises a coating or a body and the method further comprises the step of finishing the exterior surface of the coating or body by electro-polishing, electro-chemical grinding, or chemical-mechanical finishing.

48. The method of claim 35 further comprising the step of removing the adherent array of thin film deposits from the mandrel, mechanically, thermochemically, or by chemical dissolution for the purpose of creating a free-standing body.